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HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

Bulletin No. 36.

GRASSES AND FORAGE PLANTS OF HAWAII.

BY

C. K. McCLELLAND,

Agronomist.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *June 1, 1914.*

SIR: I have the honor to submit herewith and recommend for publication as Bulletin No. 36 of the Hawaii Agricultural Experiment Station, a paper on The Grasses and Forage Plants of Hawaii, prepared by C. K. McClelland, agronomist of this station. With the increase in the population of Hawaii, the business of ranching is becoming more and more important. For many years grasses and other forage plants have been imported from various parts of the world to supplement the native forage in the Territory. Some of these imported plants have greatly added to the carrying capacity of the ranges. This bulletin gives a detailed idea of the present status of forage plants on the various Hawaiian ranches.

Very respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON, *Secretary of Agriculture.*

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GRASSES AND FORAGE PLANTS OF HAWAII.

INTRODUCTION.

The grazing industry is one of the important and profitable enterprises of Hawaii. Continual summer has eliminated the necessity of storing feed for use in winter, although in recent years there has arisen the problem of supplying feed during periods of long-continued drought.

The land that forms the basis of all of the ranches of Hawaii is rough, broken, steep, rocky, forested, or is unfitted for general agricultural purposes. Formerly large areas of arable land were included in the ranches, but much of this has been withdrawn. Eventually all arable land will be put to more economic use.

In the early days, because of the large areas of excellent pasture which were entirely unused, many domestic animals escaped, ran wild in the mountains, and there greatly increased in numbers. These wild animals became so destructive to the forests as seriously to threaten other industries which had developed, and laws were passed reserving certain areas for forest purposes, and all wild animals were ordered to be killed. But even now many wild cattle and goats are to be found.

The development of the sugar industry has created a great demand for domestic animals for draft purposes and for food for the employees. At an early date, then, the business of ranching was undertaken by corporations and by private interests.

Beyond the establishment of lines and fences and the slaughtering of the cattle for use, little was done in the way of improving the methods of management on the cattle ranches, but in more recent times many steps to do this have been taken, including—

(1) The importation of pure bred stock.
(2) The introduction of tame grasses and other forage plants.
(3) The destruction of undesirable grasses and weeds.
(4) The growing of crops and storage of feed for live stock during periods of drought and shortage of feed.

Ranching is now a definite enterprise and not a haphazard venture. The establishing of the forest reserves; the withdrawal of tillable land for the growing of sugar, pineapples, and other crops; and the

increase in population are factors which have hastened the placing of ranching upon a better basis.

The question what feeds are consumed by cattle in the forests is of little importance. It is known that they feed largely on the leaves and twigs of the trees and more especially upon the smaller undergrowth, including weeds, grasses, and other plants. As much of the forest is now reserved from such use, we are more interested in what cattle find to eat upon strictly grazing lands and as to what will form the bulk of the feed there in the future, and a study has been made of the native and introduced forage plants, their relative importance, and their value under differing conditions of environment.

As having an important bearing on the production of forage, the rainfall in various localities is given in the following table:

Average annual and monthly precipitation at some Hawaiian ranches and other points.[1]

Station.	Elevation.	Years of record.	Jan.	Feb.	Mar.	Apr.	May.	June.
Island of Hawaii:	*Feet.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Hilo	100	25	9.39	11.77	16.02	13.67	9.60	7.10
Huehue[2]	2,000	6	3.92	2.49	2.99	1.99	2.49	2.59
Humuula[2]	6,685	5	2.24	3.43	2.60	1.58	1.93	.80
Kapapala ranch	2,150	26	5.63	6.68	7.64	3.62	3.19	1.28
Kohala mill	270	16	3.82	5.02	6.70	5.62	4.14	3.23
Kukaiau mill	250	19	7.42	7.97	13.78	10.94	5.10	3.37
Napoopoo	25	10	2.33	2.21	2.53	2.40	4.32	3.13
Puakea ranch[2]	600	6	4.85	5.64	9.32	5.14	4.94	3.64
Puuwaawaa ranch[2]	2,736	6	3.62	2.86	3.27	1.71	2.32	1.12
Volcano house	4,000	13	6.30	8.55	9.72	7.45	5.52	3.34
Waimea	2,720	21	4.72	4.83	5.16	3.50	2.71	2.22
Island of Maui:								
Haleakala ranch	2,000	20	6.32	6.84	7.45	3.29	1.65	.96
Kula (Erehwon)	4,200	22	7.29	6.04	4.85	1.73	2.79	1.88
Nahiku	700	11	14.46	13.28	19.54	18.11	10.81	10.59
Waiopae ranch	1,740	14	2.81	5.10	4.12	1.62	.86	.18
Island of Oahu:								
Ahuimanu	350	21	6.45	9.52	8.76	6.44	6.94	4.08
Kaneohe	100	16	3.76	5.85	6.70	3.84	4.26	2.59
Tantalus	1,360	10	6.60	10.59	9.85	8.10	7.79	6.69
Waianae	6	18	2.88	5.30	2.23	.65	.68	.28
Waimanalo	25	18	4.21	7.11	6.39	2.18	3.02	1.51
Island of Kauai:								
Kilauea	342	27	5.76	6.55	7.79	4.81	5.27	4.02
Kealia	15	12	4.12	4.89	7.04	1.89	2.34	1.62
Grove farm	200	27	4.62	5.20	6.15	3.14	3.08	1.99
McBryde residence	900	11	8.09	6.74	10.19	4.80	3.22	4.26
Kekaha	40	20	3.30	3.63	4.14	.92	2.96	.32
Island of Molokai:								
Molokai ranch	800	12	4.80	6.65	4.39	2.43	1.27	.86

[1] Computed mainly from U. S. Dept. Agr., Weather Bur., Hawaiian Sect. Climat. Serv., Ann. Summary, 1911.

[2] Calculated from records, 1906–1911, inclusive. No record at Humuula in 1907. Average for Puakea ranch high because of an exceptionally heavy rainfall in 1909. Normal should be about 50 inches annually.

Average annual and monthly precipitation at some Hawaiian ranches and other points—Continued.

Station.	Elevation.	Years of record.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Island of Hawaii:	*Feet.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Hilo	100	25	10.46	12.56	10.66	10.97	13.09	11.24	136.53
Huehue[1]	2,000	6	1.41	2.38	3.55	2.04	1.28	3.95	31.11
Humuula[1]	6,685	5	1.94	3.25	1.48	1.67	2.25	5.38	23.72
Kapapala ranch	2,150	26	2.03	3.55	3.75	4.33	6.81	4.77	53.28
Kohala mill	270	16	4.87	4.58	3.78	3.67	5.05	5.16	55.64
Kukaiau mill	250	19	5.71	7.12	4.44	5.14	8.52	8.09	87.66
Napoopoo	25	10	2.77	4.13	4.02	2.24	1.47	2.75	34.30
Puakea ranch[1]	600	6	6.44	5.06	4.71	3.50	4.10	9.08	66.39
Puuwaawaa ranch[1]	2,736	6	3.49	1.60	3.49	1.79	1.50	2.26	29.02
Volcano house	4,000	13	4.60	7.86	4.70	5.77	8.42	6.48	78.71
Waimea	2,720	21	2.82	3.35	2.12	2.67	3.17	5.13	42.40
Island of Maui:									
Haleakala ranch	2,000	20	1.27	2.76	2.23	2.24	4.82	7.18	47.01
Kula (Erehwon)	4,200	22	1.69	3.50	2.90	1.95	2.46	3.36	37.90
Nahiku	700	11	13.18	18.33	13.39	12.31	16.93	17.38	178.31
Waiopae ranch	1,740	14	.33	.86	.45	1.12	2.43	3.05	22.93
Island of Oahu:									
Ahuimanu	350	21	4.38	5.94	6.74	6.41	8.87	9.44	83.97
Kaneohe	100	16	2.57	4.44	3.90	4.30	4.96	6.80	53.97
Tantalus	1,360	10	6.54	9.29	9.56	7.17	10.08	11.51	125.80
Waianae	6	18	.33	.99	.97	.98	2.65	2.83	20.77
Waimanalo	25	18	1.40	1.76	2.08	2.50	5.21	6.97	44.34
Island of Kauai:									
Kilauea	342	27	4.76	5.01	4.47	5.69	6.95	6.38	69.28
Kealia	15	12	1.91	1.99	2.32	3.76	3.65	4.44	39.97
Grove farm	200	27	2.21	2.73	2.76	3.62	5.50	4.86	45.86
McBryde residence	900	11	4.94	5.88	5.16	4.70	5.97	6.36	70.31
Kekaha	40	20	.45	1.14	1.12	1.20	2.64	2.76	22.64
Island of Molokai:									
Molokai ranch	800	12	1.18	.99	1.16	1.63	3.82	5.27	34.45

[1] Calculated from records, 1906–1911, inclusive. No record at Humuula in 1907. Average for Puakea ranch high because of an exceptionally heavy rainfall in 1909. Normal should be about 50 inches annually.

A study of rainfall statistics on the Hawaiian Islands reveals the fact that the average annual rainfall at any point seldom falls much below 20 inches. In the mainland States the line of 20 inches rainfall roughly follows the line of 100° west longitude and marks the line between sure and uncertain crop regions. West of that meridian much land is now taken up in "dry farming" and the balance is in ranch, mountain, or desert land.

However, the fact that the greater part of the land in Hawaii receives over 20 inches of rain does not tell the complete story. Some soils allow percolation so freely that most of the water passes beyond the reach of plants; some lands are so steep that nearly all is lost by surface drainage; the precipitation is so heavy at times that no opportunity for percolation is given, or it may be so light that all is quickly lost by evaporation. Because of heat and wind, evaporation is high at certain times and places and the drier the season and the more the need for moisture, the higher is the rate of evaporation. Some figures giving the effective annual and monthly rainfall would be of more value in determining the crop possibilities of a given region.

The nature of the vegetation determines the need for moisture. With annual weeds and grasses a heavy rainfall for a short season is best in order to start vegetation and push it to maturity.

The amount of effective precipitation from May to October largely determines the carrying capacity of a ranch. Where the monthly rainfall falls below about 2 inches, the precipitation commonly occurs in small showers and the moisture is for the most part lost. On nearly all Hawaiian ranches there occurs a shortage of feed during the summer and early fall months. Although knowing the advisability of alternating and resting the paddocks, the manager is often given no choice but must use all available feed in order to prevent the loss of his cattle. At this time grasses, sedges, and miscellaneous forage plants which are usually not relished by live stock are readily eaten, and are therefore to be considered of value. As an example, Hilo grass is the means whereby hundreds of cattle are enabled to live over the period of scarcity; prickly pear, too, becomes an important factor. It is very fortunate that the algaroba fruits at this season and thus helps out in critical periods. Some ranchers are preparing to store feed against this time of need. On the Parker ranch there is now storage room for 1,500 tons of silage, enough to furnish 1,000 head of cattle 25 pounds per day for 120 days. The erection of more silos is contemplated. The Cornwell ranch, Erehwon and Mokuleia dairies, Raymond ranch, and others have now provided similar storage. On Molokai there is a considerable acreage planted each year in corn, and the stover is shredded and baled because in this form it is possible to haul it several miles to the cattle when they are feeding upon algaroba beans and require roughage to balance their diet.

Crops which could be grown to supplement pastures include sorghum, Kafir corn, milo maize, mangel-wurzel, sugar beet, and cassava, one or more of which should prove satisfactory in the different parts of the Territory. Alfalfa would prove a great benefit, since it grows readily, but it is not always easily cured for baling.

The possible shortage of summer feed is something which all the stockmen of the drier districts now plan, but there is another shortage which at times has caused great loss. When the precipitation during the rainy season falls far below normal the annual weeds and grasses make no growth. Under this condition, the growing of supplementary crops is hazardous or impossible and there is little else to do but to reduce the size of the herds.

COMPOSITION OF SOME HAWAIIAN FEEDS.

In 1906 the Hawaii Experiment Station published a bulletin upon the Composition of Some Hawaiian Feeding Stuffs, by E. C. Shorey.[1] In later publications analyses of various grasses have been reported in addition.[2] The following table gives some analyses taken from

[1] Hawaii Sta. Bul. 13.

[2] Hawaii Sta. Rpts. 1907, p. 63; 1908, p. 58.

the above publications, some heretofore unpublished, and a few from other sources. In order to give the best comparison between these materials, only the analyses of water-free material is given and the reader is referred to the above sources for complete data.

Composition of Hawaiian feeds.

[Dry-matter basis.]

Kind of feed.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Lime.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Guinea grass	5.52	0.87	54.59	28.17	10.89	0.54
Para grass	9.10	1.11	42.92	35.96	11.06	.29
Water grass	11.23	2.44	42.21	34.48	9.55	.42
Rhodes grass	7.47	2.08	48.86	33.30	8.29	.86
Natal redtop	4.69	1.99	42.09	41.99	9.24	.....
Australian blue grass	6.31	2.00	41.20	43.22	7.27	.....
Johnson grass[1]	8.01	2 33	51.1	31.7	6.8	.....
Sudan grass	8.44	1.89	43.06	36.99	9.62	.....
Tunis grass	6.27	1.53	41.92	40.27	10.01	.....
Rescue grass	11.76	2.63	39.85	37.29	8.47	.....
Chætochloa verticillata	9.82	1.31	42.14	35.09	11.64	.....
Paspalum orbiculare	4.96	1.07	53.48	31.84	8.63	.39
Paspalum conjugatum	4.71	2.30	54.39	29.93	8.25	.26
Panicum crus-galli	12.32	2.19	36.66	38.58	10.24	.13
Bermuda grass	6.86	.58	59.84	22.93	9.83	.25
Buffalo grass	4.12	1.09	62.33	28.23	6.66	.17
Pilipiliula	5.02	.61	61.15	27.56	5.47	.03
Crab grass	10.96	1.28	48.95	26.55	10.03	.14
Pili grass	4.84	1.38	49.79	32.53	11.57	.47
Yard grass	8.41	4.58	41.25	35.51	12.23	.17
Chloris elegans	7.82	1.45	43.92	32.00	11.94	.22
Spanish clover	8.82	.76	57.57	24.89	3.93	.76
Desmodium triflorum	14.42	4.07	39.90	33.40	7.92	2.00
Alfalfa	25.26	1.76	32.25	28.85	11.23	1.30
Purslane	21.66	1.87	45.41	11.04	20.00	.62
Pualele	13.82	5.82	45.54	19.96	15.00	.77
Honohono	13.27	2.77	47.62	22.24	13.33	.54
Puaki	6.70	1.40	61.06	22.28	8.54	2.18
Prickly pear:						
Young fronds	8.19	1.30	60.33	9.68	20.85	3.16
Old fronds	7.25	1.11	58.73	11.33	21.00	4.83
Ti leaves	13.85	3.04	43.07	30.87	9.06	.53
Cassava roots	3.79	8.21	72.02	10.93	4.07	.27
Algaroba:						
Whole beans	10.36	.69	54.76	28.88	3.83	.38
Average pods, seeds removed	5.59	.18	63.10	27.29	3.81	.36
Kentucky blue grass[1]	9.9	4.9	47.9	29.2	8.0	.....
Perennial rye grass[1]	11.7	2.44	47.1	29.5	9.2	.....
Italian rye grass[1]	8.2	1.8	49.2	33.3	7.5	.....
Orchard grass[1]	9.0	2.9	45.5	36.0	6.65	.....

[1] Calculated from Henry's Feeds and Feeding. Madison, Wis., 1910, 10th ed., pp. 568, 569.

Feeds must be compared by results. The successful production of beef and mutton in Hawaii is proof of the nutritiousness of the forage. However, there is a great difference in the value of feeds which analyses do not reveal, due to palatability and digestibility. No percentages of digestibility have been worked out by feeding experiments conducted in Hawaii.

It will be noticed from the table that the analyses of grasses of Hawaii compare very favorably with the few analyses here given of tame grasses on the mainland; that several of the grasses greatly exceed others in their content of protein and fat; that honohono,

purslane, and pualele excel most of the grasses; and that the whole kiawe bean is superior to the pods only. This latter fact emphasizes the importance of grinding so as to obtain the value of the bean itself which contains 30 per cent of protein which is lost unless the seed is crushed.

E. C. Shorey and V. A. Norgaard have shown the shortage of lime in various Hawaiian feeding stuffs and called attention to the ill effects resulting from this lack and also to methods of correcting the deficiency.

According to various authorities on physiological chemistry, osteomalacia and other similar troubles, such as rickets in the human family, "pica" and "lamesickness" among animals, in which there is softening of the bone, are not always caused by lack of mineral material in the food. These diseases are caused by a disarrangement of the nutritive factors. A lack of inorganic material in the food of growing animals results in the formation of finer-boned, smaller animals. In a mother animal such lack results in the taking of material from her own bones to supply the fœtus she is carrying or to produce milk for the benefit of the young which she is nursing. Therefore, any deficiency of lime in feeding stuffs should be made up for breeding stock or growing animals.

It has been observed by many ranchmen that when animals graze on Hilo grass there is a tendency toward this reduction in size and bone. Where pasturage is known to be deficient in lime the mineral matter must be supplied by feeding bone meal with salt or with molasses.

Another deficiency of some of the pasture lands is the absence of legumes. The table shows the weeds and grasses to be more or less rich in protein but cattle need a more nitrogenous supplement for economical feeding.

On the higher lands, where hop clover, white clover, Indian clover, or red clover have become naturalized, the pasturage has been greatly improved. At low and medium elevations, Spanish clover is widely distributed. *Desmodium triflorum* grows thickly at the lower elevations, particularly with pilipiliula. Black medic and bur clover are two other legumes which, though widely distributed, are not abundant. Bur clover is spreading more rapidly on the higher than on the lower lands.

As long as grass-fattened animals satisfy the demands of local markets the present feeds, although open to improvement, will continue to be satisfactory, the greatest problem being, as stated elsewhere, to get sufficient quantity, regardless of quality, during periods of drought.

THE MORE IMPORTANT GRASSES IN HAWAII.

In the following pages notes are given on the distribution, characteristics, and value of some of the more important native and introduced grasses found on the ranches of Hawaii. Preliminary to the more detailed discussion of the various species a summary of them may be found in the following table, in which scientific and popular names and notes on their distribution are given:

The more important grasses.

Botanical name.	Common name.	Hawaiian name.	Remarks.
Andropogon contortus	Twisted beard grass	Pili	On low dry lands.
Andropogon halepensis (var.).	Johnson grass		On alfalfa and sugar lands.
Andropogon saccharoides	Fuzzy top		For low dry lands.
Anthoxanthum odoratum	Sweet vernal grass		Found in wet districts of Molokai.
Briza minor	Quaking grass		In wet regions.
Bromus unioloides	Prairie or rescue grass		At elevations of 2,000 feet and above.
Calamagrostis fosteri	Toothed bent grass	Heupuueo	Do.
Cenchrus echinatus	Sandbur or bur grass	Umealu	On dry sandy lands.
Chætochloa glauca	Yellow foxtail		Pest on Kauai.
Chætochloa verticillata	Bristly foxtail		A weedy annual.
Chloris gayana	Rhodes grass		For meadows.
Chrysopogon aciculatus		Piipii or pilipiliula	Worthless as feed.
Cynodon dactylon	Bermuda grass	Manienie	At elevations up to 5,000 feet.
Dactylis glomerata	Orchard grass or cocksfoot.		At elevations of 4,000 feet and above.
Eleusine indica	Yard grass	Manienie alii (on Molokai).	
Eragrostis variabilis		Emoloa or Kalamalo	
Festuca myurus	Rat-tail fescue		
Holcus lanatus	Yorkshire fog, velvet, or meadow soft grass.		At elevations of 4,000 to 7,000 feet.
Hordeum murinum	Wall barley		
Kœleria glomerata	Mountain pili	Pili-uka	In dry regions.
Lolium perenne	Perennial rye grass		At elevations of 4,000 feet and above.
Panicum colonum or *Echinochloa colona.*	Six weeks grass (on Molokai).		
Panicum crus-galli or *Echinochloa crus-galli.*	Barnyard grass		Along water ditches or submerged lands.
Panicum barbinode	Para grass (commonly called "panicum").		Plant in wet places.
Panicum maximum	Guinea grass		
Panicum pruriens	Crab grass	Kukaipuaa	Valuable annual, low elevations.
Panicum torridum		Kakonakona	Eaten in dry seasons.
Paspalum conjugatum	Hilo grass		
Paspalum dilatatum	Australian water grass		Good at all elevations.
Paspalum orbiculare	Rice grass	Mau-laiki	Worthless.
Poa annua	Annual meadow or low spear grass.		At elevations of 4,000 to 6,000 feet.
Poa pratensis	Kentucky blue grass		Do.
Stenotaphrum americanum	Buffalo grass	Manienie-akiaki	From sea level to elevations of 4,000 feet.
Syntherisma sanguinalis	Crab grass	Kukaipuaa	
Syntherisma helleri	....do	Kukaipuaa-uka	
Tricholæna rosea	Natal redtop		

Stenotaphrum americanum, called manienie-akiaki, buffalo grass, or in the South, St. Augustine grass, is found in all warm countries and is a valuable grass under all conditions of moisture and at all elevations, but particularly below 4,000 feet. It is aggressive in its growth when moisture conditions are good, and will, when not grazed, overrun guava, lantana, and other bushes, but not destroy them. It is an excellent grass to plant in fields abandoned because of Japanese nut

grass, or coco grass, since it forms a dense mat and furnishes abundant feed while at the same time holding the coco grass in check. It is propagated readily by cuttings of the long creeping stems. It is closely grazed, particularly by cattle, and is valued for maintenance rather than for growth or fattening. It occupies considerable areas on all of the islands, particularly on Kauai. It grows rather slowly in extremely dry locations. It is crowded out by Hilo grass where rainfall is excessive, which may be partly due to the grazing of the one and not of the other.

Chrysopogon aciculatus piipii, or pilipiliula (Pl. I, 3), is a nearly worthless grass which covers considerable areas. It has creeping stems which root from the joints. It is more aggressive than manienie and will crowd out the latter grass. It is eaten by cattle, but is of little value, and is especially objectionable for sheep because of the penetrating awns. It is easily eradicated by plowing, and where it is possible to do this better grasses may be substituted for it. *Paspalum compressum* crowds it out under the Hanalei conditions. *Paspalum dilatatum* also would be able to crowd it more or less under reasonable conditions of moisture. This grass is the principal grass upon the Wahiawa plain of Oahu, but the small clover, *Desmodium triflorum*, occurring with it furnishes the major part of the grazing.

Paspalum conjugatum, Hilo grass (Pl. II, 2), is a native of tropical America. It appeared near Hilo about 1840 and spread rapidly, crowding out many better grasses. The fact that it is less palatable than other grasses enables it to crowd them out. In rainy regions or seasons it makes a heavy growth. It is liked by stock only when kept closely cropped. The larger growth during wet seasons is grazed, but disturbs the digestion of cattle if eaten in quantity. During the dry season more of the coarser growth is consumed, because of the shortage of other food. On the Parker ranch there are over 50,000 acres of Hilo grass. It is valuable in helping to tide over the period when other feed is wanting. Better feed is obtained by burning off the old growth whenever it is possible to do so.

Under fair conditions *Paspalum dilatatum* and *P. compressum* will slowly crowd out the Hilo grass. While Hilo grass is of value, *P. dilatatum* is to be preferred and should be substituted for it whenever the conditions will permit. *Paspalum orbiculare* (Pl. II, 3), rice grass, mau-laiki, occupies large areas on windward slopes and also at higher elevations on the lee side of the islands. It is not liked by stock. The tender growth of young seedlings, of closely cropped pastures, or after burning, is better relished. The grass occurs generally throughout the guava belt. It is gathered frequently for bedding or packing purposes. It is known as cow grass in Queensland and as ditch millet in other places. Cases of poisoning have been known in India from eating the seed of this grass. The milk from

cows grazed on it is said to be narcotic and injurious.[1] Some of the ranchers of Hawaii consider it a pest; others say it is of secondary value for the maintenance of cattle only.

Paspalum dilatatum (Pl. II, 1), also known as Australian or large water grass, is a native of South America, but was introduced in 1903 from Australia, where it has been grown for about 30 years. It is one of the most valuable grasses yet introduced into Hawaii. It is true that Bermuda grass, Kentucky blue grass, and a few others, occupy larger areas, but probably the area in water grass will ultimately exceed the areas in these other grasses.

Kentucky blue grass is suited to high elevations, while the water grass does well either high or low. The same objection holds against orchard grass, soft meadow grass, and others. Bermuda is somewhat more drought resistant, but the Paspalum crowds it out when moisture is more available. While it makes little or no growth in very dry seasons, it does not die out, but starts up with the first good rains.

At sea level on the leeward coast, this grass makes fair growth only during and following the rainy season. The same may be said of it in similar situations up to an elevation of 2,000 feet or more. Topography and rainfall determine its economic value rather than elevation, while with many introduced grasses elevation is the important factor. On the windward slopes its value is likewise determined by the amount of rainfall, being greater where the rainfall is from 60 to 120 inches annually. It is not recommended for swampy regions, but rather for semihumid conditions above elevations of 1,000 or 1,500 feet, although it is valuable in the dry sections following rainy seasons, often being more valuable than the annual grasses or weeds which supply feed at such times.

In the table of composition the high nutritive properties of water grass as shown by the high content of protein and fat are apparent. From the analyses one would expect that this would be a most excellent grass for growing animals and keeping them in good condition at all times. Results show this to be true. At Princeville plantation cattle fatten on this at all seasons. Its palatability is noteworthy. In mixed growths, the water grass is kept closely cropped, while Bermuda and other grasses are allowed to grow several inches high. Finer grasses, like the gramas, are grazed even more closely than water grass when growing side by side and, not having the persistence of the water grass, gradually give way to it.

Under good conditions it is possible to make hay from this grass as well as to use it for soiling. However, because of its habit of growth, it is very difficult to mow with machine or scythe, but may be cut with Japanese grass blades. It is difficult to cure because of

[1] Maiden, J. H. A Manual of the Grasses of New South Wales, Sydney, 1898, p. 19.

the large moisture content, and the hay seems to be much less palatable than the fresh grass. Hence this grass should be considered as a pasture grass only, and as such it heads the list.

The plant has a semispreading habit of growth, but becomes more upright when thickly planted. When thinly planted, it assumes a more trailing habit, and sends out rootstocks from well established isolated plants. It spreads slowly from a rootstock growing just at the surface of the soil. Thin stands thus become better in the course of a few years. Water grass under good conditions is able to crowd out Bermuda, pilipiliula, and Hilo grass. Young plants seed profusely, but the seed ripens unevenly even in the same seed head, so that saving seed is difficult and expensive. Some recommend shaking the seed heads over a pan so as to obtain only well ripened seeds. When closely grazed little or no seed is formed, although an effort is made to form them on stems which extend well out along the ground and become vertical as the seed head emerges from the boot. The plants may seed several times annually. Some who have planted seed claim poor results, only 25 per cent or less of the seed being good. In planting, 6 to 10 pounds per acre with 3 pounds of some more rapidly growing grass should be sown. The seed weighs 17 to 35 pounds per bushel, good seed weighing at least 28 pounds.

The point to remember in seeding water grass is that germination requires moisture and the supply must hold good until the plants are well rooted, as the young seedlings will perish if the soil dries. When this happens, the failure is usually accredited to poor seed. The seeds should be covered but lightly, and a stand will be obtained much sooner if covering is done, as the seed is light. In well-prepared plowed fields, in single furrows across given areas, or scattered along trails, over sodded, rocky, or other areas, some results may always be obtained. More immediate results are obtained from better treatment, but it often happens that seed remains without germinating for several months.

The best plan is to sow the seed in a bed, water it, and transplant the well-rooted seedlings to the paddocks. Set the plants in checks 2 feet apart each way or in single lines across the field at intervals of 2, 4, 6, 10, or 20 feet apart, or simply plant in a haphazard manner here and there. Old plants may be taken up, the roots divided and planted out in the same manner as seedlings. Do not turn cattle upon newly planted fields.

The carrying capacity of water grass varies much. In Hawaii it may be said that there is a different capacity for each square mile of pasture. At the Princeville plantation, at an elevation of 300 to 800 feet, with 60 to 100 inches of rain, the carrying capacity has been one steer per acre for three years in one paddock of 40 acres. In a

1, Cynodon dactylon (Manienie); 2, Chætochloa verticillata (Bristly Foxtail); 3, Chrysopogon aciculatus (Pilipiliula).

1, PASPALUM DILATATUM (AUSTRALIAN WATER GRASS); 2, PASPALUM CONJUGATUM (HILO GRASS); 3, PASPALUM ORBICULARE (MAU-LAIKI).

paddock of 450 acres 500 head were carried for one year, then 180 head for 10 months, then after 2 months 100 head were turned in. More were added until full capacity was reached. The carrying capacity varies with age and amount of growth of the grasses when the cattle are turned in, and also with precipitation.

To sum up, water grass is one of the best grasses introduced into Hawaii. It is valued (1) for its ability to grow under varied conditions of soil, moisture, or elevation; (2) it is easy to establish from seed or by division of the roots; (3) for its drought resistance; (4) for its persistence—its ability to survive overstocking; (5) for its palatability and nutritive properties; and (6) for the large amount of feed it produces and because it seeds freely.

Paspalum virgatum is closely related to the preceding and of about equal value. It has been tried on Maui, and more extensively on Kauai, where it has been planted over a 500-acre paddock (on Princeville plantation) in a mixture with *P. dilatatum* and *P. compressum*. The seed is high in price, but as the plant seeds profusely, the area could be rapidly extended from a small first planting. The seeds have great vitality and will remain in the soil until the conditions for germination are favorable.

This grass is vigorous in its growth, holding its own against native or Hilo grasses. Whether it will be as persistent as *P. dilatatum* under conditions of overstocking or during long periods of drought is not definitely known. It is more erect in growth than the other species and is therefore a better forage or soiling grass. Several cuttings annually may be made if moisture conditions are always favorable. The grass may be propagated by root division.

Paspalum compressum, now known as *Axonopus compressus*, Louisiana, carpet, or Gazon grass, is quite common in the South, and is considered valuable, especially on poor lands. It is creeping in its habit of growth, making a fair lawn if kept closely clipped, but is of no value for hay. It thrives better in moist situations and suffers from continued drought. It is relished by all kinds of stock and stands grazing and tramping well. It spreads by runners and by seed, and under moist conditions will crowd out many other grasses. In southwest Texas it is said to have revolutionized the stock industry.

In Hawaii the grass is favorably reported from Princeville plantation, Kauai. There it crowds out Hilo grass, pilipiliula, and all weeds, and grasses except *P. dilatatum* and *P. virgatum*. It becomes dormant in dry weather, but starts up with the first rains. It was kept closely grazed, but survived and started up well when the cattle were taken off. The seeds, it was thought, were scattered by rice birds, as plants were found 2 miles from the original planting. Like the two preceding species, some time and much moisture are required

to start the seeds and the grass comes up long after one has despaired of it and given a verdict of "bad seed."

Judging from one season's trial at the experiment station it is fully as drought resistant as *P. dilatatum*, but under these conditions is much less vigorous in its growth, and although it spreads more rapidly because of its creeping stems or runners, it furnishes less feed than *P. dilatatum*. Were it strong enough to crowd out the latter grass, the advisability of planting it might be questioned, but as it has not done this, it seems to be of value and may be planted in mixtures.

Holcus lanatus, velvet grass, meadow soft grass, or Yorkshire fog, commonly called mesquite in Hawaii, is, according to M. J. Sutton,[1] "one of the most persistent and troublesome of the worthless grasses, possessing structural endowments which insure its continued existence under extremely varied conditions." These "endowments," however, make the grass of value in Hawaii. At elevations of from 4,000 to 7,000 feet this becomes one of the main pasture grasses. It is able to withstand drought and frost. It thrives also under better moisture conditions.

In Australia the grass is little liked, and in Oregon and Washington it occurs as a weed among better meadow grasses. While no doubt of less value than Kentucky blue grass or orchard grass, at certain seasons in Hawaiian pastures it is of great value in mixtures, and at the higher elevations particularly.

Poa pratensis, Kentucky blue grass, was introduced into Hawaii by Captain Makee at Ulupalakua about 1879 or 1880. This grass is one of the principal pasture grasses of the humid portion of the United States, Canada, and other countries, and its value is too well known to require comment. It is persistent against drought or overstocking, becomes green and grows with the first rains, but becomes dry and brown during the hot, dry months. Stock on blue-grass pasture require other feed at such times to obtain best results. This grass occupies considerable areas in Hawaii, between 4,000 and 6,000 feet in elevation on Ulupalakua, Haleakala, Parker ranch, Humuula, Puuwaawaa, and in the Konas. It furnishes grazing for about four or five months and carries one head for every 3 or 4 acres for that length of time. Wherever found it is a fine fattening grass.

Dactylis glomerata, orchard or cocksfoot grass, occupies large areas in Hawaii at elevations of 4,000 to 6,000 feet. It is a large, coarse grass, occurs in clumps rather than in an even sod, does not spread, and is of slightly less value than Kentucky blue grass for fattening, although it is a palatable, nutritious grass. It also becomes dry and brown during times of drought, but there is some feed available

[1] Permanent and Temporary Pastures. London, 1902, 6th ed., p. 150.

from this grass at such times. The name orchard grass was applied to it because of its general use in orchards. It makes an excellent nurse crop for *Paspalum dilatatum*. It spreads chiefly from seed and is easily crowded out by Hilo grass, especially when closely grazed.

Lolium perenne, perennial rye grass, is rarely perennial in Hawaii. It is adapted to the higher pastures (4,000 to 6,500 feet), where it furnishes good grazing. It will withstand any amount of treading and grazing, but dies out gradually in periods of drought. At medium elevations it would likely prove a good nurse crop for *Paspalum dilatatum*. It is recommended for all mixtures for permanent pastures.

Bromus unioloides, rescue grass, Australian prairie grass, Schrader's brome grass, is classed as a perennial, but becomes annual under unfavorable conditions. It grows well at lower elevations only during the cooler months, but seeds abundantly, and young plants are found the following year. However, it makes its best growth at higher elevations with lower temperatures. It is not injured by frost and is valuable near the frost line on the mountain pastures of Hawaii. It is shallow rooted, and large clumps are easily uprooted by live stock, but under continual grazing or when in mixtures with other grasses, this objection is not so great. At medium elevations on the Parker ranch isolated patches of this grass may be seen, single small seed heads appearing a few inches above the Bermuda sod. It is reported to have crowded out several thousand acres of manienie in the last 28 years in the vicinity of Wood's ranch, Kohala, Hawaii. According to the analysis its nutritive value is very high.

Kœleria glomerata, mountain pili, is the principal indigenous grass occurring at high elevations. It is found covering large areas on the higher lands of Parker's, Hind's, Shipman's, and other ranches of Hawaii. Rock states that he has found it at elevations above 8,000 feet, and that it is about the last species observed in ascending the mountains.[1]

Calamagrostis forsteri, heupuueo, is an annual, appearing at elevations above 2,000 feet following the rainy season. During the dry season, or after the seed has fallen, the dry, naked, open panicle becomes conspicuous. These empty panicles, driven by the wind, often collect in strawlike masses at the base of guava or other shrubs. The feeding value is fairly high; the grass is palatable and nutritious. It remains green for but a few months. This grass is quite widely distributed.

Festuca myurus, rat-tail fescue, occurs at elevations of 2,000 feet and above. The seed heads are conspicuous when standing out above the manienie or pilipiliula sod. The leaf is narrow and

[1] Rock, J. F. The Indigenous Trees of the Hawaiian Islands. Honolulu, 1913, p. 47.

appears to be nearly round. The grass is widely distributed at medium and high elevations and is of but medium value as a forage crop. It persists long and does not appear to be grazed when the seed is maturing.

Briza minor, quaking grass, occurs also at upper medium elevations and more thickly in regions of frequent showers and where the rainfall is heavy and continuous. It has some feeding value, but is crowded out on grazing lands by Hilo grass, or maulaiki.

Cynodon dactylon, Bermuda grass (Pl. I, 1) is a much-prized as well as a much-abused grass, which occupies large areas of the pasture lands of Hawaii. It was introduced about 1835 and covers a greater area than any other one grass. The native grasses and the majority of the tame grasses spring up with the rains, flourish for a time, and with the coming of the dry season disappear, while the manienie survives the severest drought; although in the most severe ones it may make no active growth for a long period. Many perennials succumb to bad treatment, but this grass, no matter how much abused, or how long the drought may continue, springs up at once when conditions improve.

Manienie spreads by creeping rootstocks which throw up stems from each joint, and also by running stems above the ground which root at each joint. It also spreads by seed. It is usually propagated by cutting sods into small pieces, which are then set out 2 feet apart each way in the fields where desired. A field planted in this manner will soon be covered.

It is not a hay grass in Hawaii. Bermuda grass is one of the most valuable of lawn grasses for hot climates. It is of great value as a soil-binding grass and is planted along terraces on hilly land, dikes, or rice fields, and upon the sands of the seashore. On Lanai 5,000 acres of wind-eroded soil was saved by planting Bermuda grass. Its composition and digestibility are shown in the following table:

Composition and digestibility of Bermuda grass.

Constituents.	Bermuda grass.[1]	Bermuda hay, first year after planting.[2]		Bermuda hay.[3]	
	Composition.	Composition.	Digestibility.	Composition.	Digestibility.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Protein	6.86	18.72	64.19	6.43	48.80
Fat	.58	2.49	39.69	1.60	46.90
Fiber	22.93	21.57	58.93	27.62	50.80
Nitrogen-free extract	59.84	40.71	52.71	46.70	50.20
Ash	9.83	9.13	41.68	7.88	28.00
Water	.....	7.38	.....	9.74	.....

[1] Hawaii Sta. Bul. 13. The analysis is given for the water-free material. The fresh material contains about 45 per cent of water.

[2] Oklahoma Sta. Bul. 90. Analyses in the second and third years showed a reduction in the protein content to 11.9 and an increase in the fiber and nitrogen-free extract.

[3] Texas Sta. Bul. 147.

1, PANICUM MAXIMUM (GUINEA GRASS); 2, PANICUM COLONUM; 3, PANICUM CRUS-GALLI (BARNYARD GRASS).

1, PANICUM PRURIENS (KUKAIPUAA); 2, ELEUSINE ÆGYPTIACA; 3, ELEUSINE INDICA (YARD GRASS).

It will be seen from the table that manienie has a fairly good composition, but that the digestibility is rather low. The Oklahoma analyses indicate that young plants produce more nutritious feed than older ones. The feeding value often coincides with the palatability. It is well known that manienie is more relished by live stock when it is kept closely grazed.

The objections to manienie are that it is difficult to eradicate when firmly established, it spreads too rapidly in cultivated fields, and it is not sufficiently nutritious. It is good for maintenance, less so for growth, and of little value for fattening unless the cattle have access to other feed. Horses seem to keep in better condition upon it than do cattle. Another objection to it is that in dry seasons it may cause the loss of many animals through a form of "staggers." Cattle should have access to water when pastured on dry Bermuda; hence mountain cattle unused to water sometimes suffer from this disease.

Panicum crus-galli or *Echinochloa crus-galli* (Pl. III, 3), barnyard grass, is a coarse weedy grass in rice and taro fields and along irrigation ditches. When in sufficient amounts it is cut and used for green feed. With the ratoons of the rice crop, it affords considerable grazing for the water buffalo and other draft animals of the rice planters.

Panicum frumentaceum or *Echinochloa frumentacea* (cultivated in India as grain) is another species occurring with the above and not distinguishable from it except by botanists. There are several varieties of the barnyard grass itself, the variations being in botanical characters mainly. It is a widely distributed species, and although it becomes a weed in tilled fields it is easily kept in control. It sometimes produces a hay crop after the removal of a cultivated crop. It is a very nutritious grass, being rich in protein and fat.

Panicum colonum or *Echinochloa colona* (Pl. III, 2) is also similar to the barnyard grass and is often found with it. This species is smaller, however, and prefers less moist situations. It springs up after rains and furnishes grazing for a short time only, as it soon seeds and dies down. It occurs abundantly in wide rocky gulches or valleys on Molokai at low elevations. There it is known as "six-weeks" grass, but in other countries it is called jungle rice.

Chætochloa verticillata (Pl. I, 2), or bristly foxtail grass, occurs plentifully about Honolulu. It grows very rapidly after good rains, and is cut by many of the dairymen and used as a soiling crop. It is considered equal, or superior, to Para grass for milk production. The mature grass is of less value. Horses do not seem to like it. It is a troublesome weed in cultivated fields where the seed is always present, ready to spring up when moisture is supplied. The beards have a hook or barb, and when the heads are mature they cling to manes and tails of animals or to the clothes of any one passing and are thus distributed.

Chætochloa glauca is a pest over several hundreds of acres near Lihue, Kauai, and occurs in less amounts upon various Kauai ranches. Attempts are being made to eradicate it. The seed was introduced in hay from California. The grass has little forage value, and it is not very well liked by live stock. In cultivated fields it is difficult to eradicate. It springs up after the crops are laid by, seeds so abundantly, and the seeds retain their vitality so long that the land seems to be irredeemably foul.

Hordeum murinum, wall barley, known on the Parker ranch as California grass, because it was introduced in California hay, occurs on many ranches and plantations and furnishes considerable feed. It is quite palatable and is grazed more or less closely until the heads appear, when it is objectionable to the stock on account of the long beards. It is a low-growing grass, closely resembling bearded barley in appearance. It grows best where it receives the benefit of surface drainage or subirrigation.

Panicum pruriens (Pl. IV, 1), kukaipuaa, crab grass, and *Syntherisma sanguinalis*, kukaipuaa, or crab grass, and *S. helleri* are considered identical by all of the ranchmen. Kukaipuaa is the name applied to annual species, which are weeds in cultivated fields, but which furnish a very valuable feed in the paddocks. If allowed to grow undisturbed the reclining stems root at several joints from the central crown, then become vertical, and bloom. The seed head is "crowfoot" in shape, like that of manienie and yard grass. Kukaipuaa is very nutritious. With various annual weeds it becomes an important fattening feed in paddocks where perennial grasses do not thrive. It occurs at all elevations and under all degrees of rainfall. It was formerly abundant in Puna, but has been crowded out by Hilo grass.

Eleusine indica (Pl. IV, 3), manienie alii, and *E. ægyptiaca*, yard grasses, crowfoot, or goose grasses are drought-resistant grasses occurring widely over the Territory. *E. indica* is a pest in the lawns and along the roadsides of Honolulu. On Molokai it is a weed in the alfalfa fields. It is a tough grass well liked by horses and cattle. It is valuable on extremely dry ranges or along and above the algaroba belts. The toughness of the stems is overbalanced by its good seeding, persistence, palatability, nutritiousness, and drought- resisting qualities. It is rather coarse and has a typical "crowfoot" seed head.

Panicum torridum, kakonakona, is a valuable annual grass occurring at low elevations during and following the rainy season. It is very fattening, and well liked by live stock. It is the main fattening grass on the lower elevations of dry ranches. It is reported as an excellent grass on Molokai, Ulupalakua, Cornwell, and Haleakala ranches, and is of value in other locations. It occurs mixed with other annual grasses and weeds. The only objection to it is its short season of

growth. However, it materially helps out in the feed problem on lands where perennial grasses do not thrive or are not yet established.

Cenchrus echinatus (Pl. V, 2), umealu, sandbur, is well distributed up to about 4,000 feet, but occurs in thicker stands below 1,000 or 1,200 feet elevation. While the grass is young it furnishes excellent feed, but when the burs are forming it is of no value. The burs are troublesome, particularly in the wool of sheep. Nevertheless, the grass is highly valued on some of the sheep ranches, though it causes some loss through the reduced price received for the wool. It is valuable on the lower dry lands where perennial grasses do not thrive, along with kakonakona and other annuals. It is very drought-resistant and prefers sandy, dry locations. It has been widely scattered in baled alfalfa hay. Because of its ability to withstand dry conditions, and reseed itself in spite of heavy grazing, and because of its longer season of growth it is recommended for feed on lands where better grasses will not grow.

Panicum barbinode, Para grass (Pl. VI, fig. 1), has become generally known in Hawaii as "panicum" grass.[1] This grass was introduced from Fiji in 1902, and was soon well distributed over the islands. As it does not seed profusely it is propagated entirely by sections of the long jointed stems which strike root readily when embedded in damp soil. Because of the trailing habit of growth of these stems, the grass will soon occupy a field even when thinly planted. As the roots are shallow, the grass can easily be eradicated when not wanted.

The grass is grown in all parts of Hawaii under heavy rainfall or irrigation as a green soiling crop for horses and dairy cattle. No attempt at haymaking is made. As a pasture grass it is used to some extent, but reports as to its value are rather meager. It is palatable, fairly nutritious, although somewhat coarse and fibrous. It does not stand pasturing well. All the good results with Para grass are reported from low, wet lands, and failures from high, dry lands.

Panicum grass is primarily a wet-land grass and requires an abundance of water. Even an excess of water will not injure it, and it can be planted in marshy places where other grasses would not thrive. Semimarshy lands are often dried out by planting Para grass upon them, thus making them less dangerous as places for the miring of stock. The grass is not killed by overflows.

The yields obtained vary with the fertility and moisture. At the Glenwood substation, with heavy rainfall, and where the manure was returned to the plat, a yield at the rate of 31 tons per acre of green forage in four cuttings was obtained within nine months of planting. At Hanalei four or five crops per year are obtained, the grass being

[1] Hawaii. Forester and Agr., 4 (1907), p. 277.

cut up with Guinea grass for horses and mules. Good results have been obtained by top-dressing with stable manure or bone meal.

Melinis minutiflora, molasses or Brazilian grass (Pl. VII, fig. 1), seed of which was recently received from Washington, grows very slowly. It bloomed during November. A portion of the plants cut back in July ratooned well. The habit of growth of this grass resembles that of Para grass.

Chloris gayana, *C. virgata*, Rhodes grass (Pl. VIII, 2), native of South Africa, was introduced into Hawaii from Australia in 1904. From the small area sown that year on Molokai ranch, seed was saved and another planting made the following year, and the area gradually extended. Forty acres are now in Rhodes grass on Molokai, and the same area on the Parker ranch. These are the largest and most successful experiments which have been made with Rhodes grass in the Territory. Considerable quantities of the seed have been scattered in other places upon these and other ranches.

The grass is one of the best drought-resistant species ever tried here. It is suited to medium elevations on leeward slopes. It has an upright habit of growth, forming the seed head at from 2 to 4½ feet. In moist locations the plants stool. The outside stems are nearly horizontal at first, then becoming vertical to throw out the flower stalk. These stems often root at the joints. Another habit of growth noticeable in newly planted fields and where the plants are not crowded is the formation of runners extending as far as 6 to 8 feet from the parent plant. These runners root at the joints.

This is a valuable grass for haymaking purposes, and it is about the only grass cured for hay in Hawaii. The stems are small and cure readily. The best hay is made when the grass is cut in early bloom, since the stems become woody and tough if the seed is allowed to mature. On a Molokai ranch meadow, five cuttings have been obtained annually, the yields averaging now about one-third of a ton per cutting. The stand is thinner than formerly and the yields are less than were at first obtained. Apparently rotation of crops is as necessary with Rhodes grass meadows as it is with timothy and other meadows elsewhere. At the Glenwood substation this grass failed to ratoon when cut.

As a pasture grass Rhodes grass has not been a complete success. This failure is due principally to poor quality of seed, to the necessity for a perfect seed bed, to its shallow root system, and possibly to the fact that the cattle are too fond of it and graze it too closely or pull it up. On the Molokai ranch the sweepings from the haymows and seed otherwise collected have been sown, and yet there is practically no Rhodes grass to be seen upon the range to-day.

On Haleakala ranch, where Rhodes grass and water grass were planted on old cornlands which were later opened to grazing, the

1, ANDROPOGON CONTORTUS (PILI); 2, CENCHRUS ECHINATUS (UMEALU); 3, ERAGROSTIS UNIOLOIDES; 4, ERAGROSTIS PLUMOSA.

FIG. 1.—PANICUM BARBINODE (PARA GRASS OR PANICUM).

FIG. 2.—PANICUM MAXIMUM (GUINEA GRASS).

FIG. 1.—MELINIS MINUTIFLORA (MOLASSES GRASS).

[Planted Feb. 18, photographed Dec. 18, 1913.]

FIG. 2.—ANDROPOGON SORGHUM VARIETIES (*a*, SUDAN GRASS; *b*, TUNIS GRASS).

[Photographed 67 days from planting.]

1, CHLORIS RADIATA; 2, CHLORIS GAYANA (RHODES GRASS); 3, CHLORIS ELEGANS.

water grass is abundant while but few of the old stumps of Rhodes grass remain.

The establishment of a Rhodes-grass pasture depends on good seed, thorough preparation of the land, protection from stock until the grass is well rooted, prevention of overgrazing, and allowing the grass opportunity to recover at certain intervals. It requires the same care as does pili grass. Rhodes grass is giving the best results on Molokai, Lanai, leeward parts of Maui, and of Hawaii.

The feeding value of Rhodes grass is medium, being superior to Guinea, Natal redtop, and some others, though inferior to water grass, rescue grass, and others, as shown in the table of composition. It is of less value for fattening than for maintenance or growth.

The seed is worth 30 to 40 cents per pound, and 2 pounds are said to be enough for an acre. The difficulties in obtaining a stand have already been mentioned. Good seed must be secured and planted under good conditions. Broadcasting upon unprepared fields is a waste of time and seed. At the experiment station no dependence is placed on seed, but additional areas are planted by dividing the roots of old plants. Mr. James Munro, of Molokai, is authority for the statement that seed saved when the first leaf below the seed head is yellowing will be good seed. Seed from young plants is better filled out and heavier than that from older plants. Further study of the quality of seed should be made.

Panicum maximum, Guinea grass (Pl. VI, fig. 2), is an African grass, well distributed over the West Indian Islands. It is propagated readily by seed, or by division of the roots (or by transplanting seedlings). It differs from Para grass in its habit of growth and in preferring better drained soils, but, like Para grass, it is used principally as a soiling crop and makes better yields when well irrigated and fertilized. It has an upright habit of growth and attains a height of 6 to 10 feet. When to be cut up for feed this maximum growth may be allowed, but when fed without running through a feed cutter (particularly to horses) more frequent cutting is preferable, as the grass becomes coarse at the base. The slow growth made during a dry season is tough and unpalatable. It should be cut from four to eight times annually, and should not be allowed to seed, if the best quality of feed is desired.

Roots or seedlings are planted 2 feet apart in the row, in rows 5 feet apart, fertilized and irrigated. Since it is a bunch grass it can not readily be cut with a machine, and is of value only on small areas where hand cutting is economical. It is not recommended in Hawaii as a pasture grass.

At Princeville plantation, on Kauai, 16 acres of Guinea and 4 acres of Para grasses are required to carry 40 head of mules and horses. The Guinea grass grows slowly during the winter months and the

manager plans to have a full growth by October 1 as a reserve on which to draw during those months.

Tricholæna rosea, Natal redtop, is another African grass which has been well tried out in the Territory. It is primarily a hay grass, but has some value for grazing. Much of the seed to be had is not good. When started, however, it grows rapidly and stools wonderfully. Seed was planted on a plat at the experiment station in November, 1912, and three months later the plants were over 2 feet high and blooming. One month later isolated plants showed over 300 flowering stems. The young growth is tender, but the old stems are wiry and tough. The grass ratoons readily if there is sufficient moisture present to start growth, and may make four to six crops annually. It is easily cut and cured for hay, but according to the composition, it is rather poor in quality.

On the Molokai ranch Mr. Munro observed that this grass seeded heavily at the beginning and close of the rainy season and would not stand close grazing in the paddocks. The writer observed that practically all of the Natal redtop was in protected or inaccessible places, and that it did not withstand grazing. On the Haleakala ranch it occurs more frequently than upon Molokai and is valued for semidry places of medium elevation. At Princeville plantation the greatest value was obtained when planted with *Paspalum dilatatum*, to furnish early feed until the latter became established. As a pasture grass Natal redtop is recommended for dry or semidry locations (or for a nurse crop for water grass in humid sections) of medium to low elevation. It should never be overstocked and should be allowed a period of rest for recuperation and seeding, as is recommended for Rhodes grass and pili.

Andropogon sericeus, Australian blue grass, is perhaps the best of the Australian blue grasses. It closely resembles Natal redtop until headed out. It is a soft-bearded grass, with good seeding habits and easily established. It is slightly superior to Natal redtop in composition and will apparently outyield it. Like the latter, it is a hay grass, "valuable alike for pasture and for hay, very fattening, and much liked by stock of all kinds."[1] It has not been tried out as a pasture grass in Hawaii, but from its similarity to Natal redtop it should probably succeed under the same treatment as recommended for that grass.

Andropogon saccharoides, feather blue stem, feather sedge, or fuzzy top grass, is found on Molokai and Niihau ranches, and on the leeward side of Kauai.

Andropogon (*Heteropogon*) *contortus*, twisted beard grass, tangle head, pili, is well known, being widely distributed. It occurs from

[1] Maiden, J. H., loc. cit., p. 78.

sea level to nearly 5,000 feet, although it thrives best below about 1,500 feet.

It formerly covered larger areas than at present, but has been destroyed or crowded out by overstocking and by the encroaching of Hilo, manienie, pilipiliula, and other grasses. The old Hawaiians utilized this grass in making their grass houses. There are extensive areas of it on western Molokai, on Lanai, in the valleys of Maui, and on leeward Hawaii. Over large areas in other regions the pili has been nearly eradicated and it is only in the inaccessible places along the sides of steep gulches that occasional clumps may be seen. The grass makes a rapid growth, starting up with the first good showers, but after seeding it becomes dry and brown. It may seed at irregular intervals, depending upon the distribution and amount of rainfall. The green growth is tender and palatable, but the brown stems are coarse and tough, and can be recommended only as maintenance feed for mature animals, although the disappearance of the grass as noted is due to grazing of the old plants as well as of the fresh growth. There is said to be a comparatively small shrinkage in cattle fattened on pili grass. Although the grass is perennial it is necessary to insure reseeding by removal of the stock, since many clumps are uprooted or injured by the stock. Pili seems to be "coming back" upon certain lower areas of the Molokai ranch, where careful management is being exercised.

On dry lands at lower elevations an effort should be made to retain pili by never overstocking, and by allowing rest at intervals. The seeds are quite difficult to collect and it would be tedious work to make new seedlings over extensive areas. With imperfect stands of pili about 15 acres per head of cattle are required.

Leptochloa virgata, Judd grass, is another grass that may be of value for hay or pasture. At the experiment station and at Haleakala ranch it promises well. The grass was introduced only recently from Bermuda, but is worthy of trial. No grazing tests have been made.

Andropogon halepensis or *Sorghum halepense*, Johnson grass, also known as evergreen millet, is considered a pest in the cotton and corn lands of the South. The grass spreads rapidly by seed and by an underground rootstock and when once started is already out of control. The hay crop upon Johnson grass infested land, however, has often been sold for more than the corn or cotton that would have been produced at the additional expense of fighting the grass, and therefore, much of the infested land has been set aside as meadow land. Although the grass is primarily a hay grass, producing but little when continually grazed, yet it is not entirely satisfactory for hay, since the growth is uneven. It is easily cured and makes a valuable feed. The best quality of hay is obtained when cut before the stems become

coarse and hard. Several cuttings annually are made. From 1 to 2 bushels of seed have been recommended per acre, and thin stands may be thickened by allowing seed to mature and fall. In old meadows the rootstocks become matted near the surface and the crop is affected by drought. Such meadows are benefited by plowing every third or fourth year.

The grass is drought resistant, nutritious, and palatable. The only objections to it are its inability to withstand a close pasturing, and the difficulty of eradicating it from cultivated fields. Small areas can be cleaned by confining hogs thereon. Plowing when very dry and raking out the stems with spike-tooth harrows is only partially effective.

To eradicate Johnson grass, pasture closely or cut frequently for about two seasons, then plow shallow; put in a cultivated crop and cultivate thoroughly.

In Hawaii Johnson grass has been planted in various places. It is more or less of a pest in alfalfa fields on Oahu, and occurs in some of the cane fields along the Kahului Railroad, on Maui.

The two following grasses are recommended for planting in preference to Johnson grass, since they can be easily destroyed when the land is wanted for other crops. According to some reports given in the meetings of the Hawaiian Live Stock Breeder's Association, Johnson grass thrives up to 2,000 feet, while other reports say that 600 feet is too high for it. Some reported it as well liked by cattle, while Mr. Isenberg stated that cattle at Waialae preferred almost anything else to Johnson grass.

Andropogon sorghum var., Sudan grass (Pl. VII, fig. 2, *a*), another African grass, closely resembling Johnson grass, but without its underground rootstock, has recently been introduced and distributed to a few of the ranches. At the experiment station this grass in a small trial plat, with frequent light showers in the spring of 1913, made a growth of 4 feet 9 inches to 5 feet, and began flowering in 55 days from planting the seed. Good reports of it have been received from Haleakala ranch and from Princeville plantation. Tests in various parts of the United States have been made and favorable reports received as to its value. The table of composition shows it to be above the average in feeding value. Horses are extremely fond of it green or dry, and no doubt the same will hold true with other stock.

Sudan grass ratoons readily, but judging from a single ratoon crop, grown in the dry month of August at Honolulu, the ratoon crop will not be as valuable as the first crop. The first crop had many fine stems; the ratoon crop had a few much larger ones, which is objectionable. Further experiments will determine its value. The seeds are large and well liked by stock and also by birds. This grass and the one preceding and following are small sorghums, and may be easily

distinguished from other grasses. Sudan grass is not easily distinguished from Tunis grass. It grows more rapidly at first, has broader leaves, and is a better feed.

Andropogon sorghum var., Tunis grass (Pl. VII, fig. 2, *b*), is very similar to the Sudan grass, but has longer narrow panicles, and sheds its seed very readily. It has the same good points as Sudan grass, but to a less degree.

LEGUMINOUS FORAGE PLANTS.

The leaves of leguminous trees furnish some grazing, particularly for cattle. The koa and mamani at higher elevations are the principal trees with forage value. At lower elevations and upon leeward sides the kiawe is very important. It is more fully described below. The leaves of the shrub known as koahaole are eaten by cattle and horses, but are said to cause the falling of hair from mane and tail of horses. Weedy plants, like the inikoa and the auhuhu, have some forage value.

Of the smaller plants, the white clover, hop clover, Indian clover, and bur clover are very valuable at higher elevations and are becoming more widespread. Spanish clover thrives at medium and low elevations but occurs only as isolated plants. The related species, *Desmodium triflorum*, occurs more thickly; it is a small creeping cloverlike plant having purple flowers and thrives well with manienie or pilipiliula. The black medic (having yellow flowers and sometimes used medicinally by the Hawaiians) is also widely distributed. Japan clover or lespedeza, which has proved valuable in the Southern States, has so far failed under Hawaiian conditions, although tried by several experimenters. Fenugreek grows well but does not reseed itself and soon disappears. Crimson clover, Egyptian clover, and red clover thrive under certain conditions but have little value on the range. Alfalfa thrives in certain places, but when once established is considered too valuable for pasturage, although it is excellent for this purpose, particularly for hogs and horses. The following table shows the principal native and introduced leguminous forage plants of Hawaii:

Leguminous forage plants.

Botanical name.	Common name.	Hawaiian name.	Remarks.
Acacia koa		Koa	Leaves are eaten by cattle.
Cytisus proliferus[1]	Tagosaste, tree lucern		
Desmodium tortuosum[1]	Florida beggarweed		
Desmodium triflorum			
Desmodium uncinatum	Spanish clover	Kikania pilipili, Pua pilipili, ihi, ilioha.	Widely distributed annual.
Dolichos lablab		Papapa	Rare on ranges.
Hedysarum coronarium[1]	Spanish sulla		
Indigofera anil	Indigo	Inikoa	Has some forage value.
Lespedeza striata[1]	Japan clover		

[1] Plants which have been introduced but are not naturalized. Some have disappeared.

Leguminous forage plants—Continued.

Botanical name.	Common name.	Hawaiian name.	Remarks.
Leucæna glauca	Koa bush	Koahaole	Leaves and pods eaten.
Medicago apiculata[1]			
Medicago denticulata	California bur clover		At all elevations during cooler months.
Medicago lupulina	Black medic, hop clover		At all elevations.
Medicago sativa	Alfalfa		
Melilotus indica	Sour or Indian clover		At high elevations.
Melilotus officinalis[1]	Yellow sweet clover		Do.
Mimosa pudica	Sensitive plant	Puahilahila	Leaves eaten by sheep.
Phaseolus semierectus			
Phaseolus retusa[1]			
Prosopis juliflora	Algaroba	Kiawe	Pods and beans eaten.
Sophora chrysophylla		Mamani	Leaves are eaten.
Tephrosia purpurea		Auhola	
Trifolium alexandrinum[1]	Egyptian clover		For wet places; low elevations.
Trifolium hybridum[1]	Alsike clover		High places having plenty of moisture.
Trifolium incarnatum[1]	Crimson clover		Cool months only.
Trifolium pratense[1]	Red clover		High places only.
Trifolium procumbens	Hop clover		High places having plenty of moisture.
Trifolium repens	White clover		Do.
Trigonella fœnum-græcum.[1]	Fenugreek		
Ulex europæus	Gorse, furze		
Vicia leavenworthi[1]	Stolley vetch		
Vicia sativa	Oregon vetch		

[1] Plants which have been introduced but are not naturalized. Some have disappeared.

Prosopis juliflora, the algaroba tree, or kiawe, as it is known, is one of the most valuable sources of feed in Hawaii. It is one of the mesquite trees. It was introduced into Hawaii in 1828, covers extensive areas, and will eventually cover all the lower elevations not devoted to cultivated crops. The algaroba is admirably suited to dry regions. It is found in large tracts on the leeward sides of the islands. Although found at greater elevations, it occurs mostly below 1,000 feet, probably because of its preference for dry localities. The tree is a source of a large part of the honey produced in the island. The wood is very valuable for fuel. The ranchers most dependent upon the algaroba find it to their interests to carry on a honey business in connection with their other work, but it is here considered merely as a feed for stock. The pods contain a number of seeds, encased in a hard seed coat, and surrounded by a sugary, gummy substance. The analysis of the entire pod is given by Shorey[1] as: Water, 15.26 per cent; protein, 8.89; fat, 0.58; nitrogen-free extract, 47.27; crude fiber, 24.75; and ash, 3.25 per cent. The beans of the algaroba, being protected by a hard seed coat, escape mastication and digestion and pass through the alimentary tract entire. This fact accounts largely for the rapid and widespread distribution of this species in the islands. Domestic animals have been the greatest factor in scattering the seed.

For several years experiments in milling the pods proved of no avail. The sugary pulp gradually accumulated upon the crushers or

[1] Hawaii Sta. Bul. 13.

rollers of the mill and caused a heating of the machinery. To secure the full feeding value of the pod grinding in some manner was necessary. Experiments were continued until the successful grinding of the pods was accomplished by two methods:

(1) By kiln drying the pods and grinding in the mills used for making alfalfa meal.

(2) By using a machine, devised by C. W. Renear, of Honolulu, in which a small spray of water is used to keep the rolls clear of the gummy substance.

The finished product obtained by the first method is fine, while the product of the second is coarse. As to the difference in feeding value, nothing is known. In both methods, however, the seed is crushed and more of the full value should be obtained.

While to the dairyman, liveryman, contractor, plantation manager, or to others who feed their animals in barns or yards the grinding of feed will result in saving, yet to the ranchman this saving is not possible, since his stock pick up the beans and consume them on the spot.

Women, children, and aged or infirm men of various nationalities pick up the beans along the roadsides, in yards, or in unused fields and sell them to consumers and to the feed mills at 10 and 15 cents per barley bag.

The algaroba is a great help to ranchmen in carrying their stock through the dry season. In years of drought there is some loss of the cattle for want of feed, and this time of scarcity has been bridged over by the algaroba in a satisfactory manner. The pods fall from June until November, but the heaviest fall is during July and August, or just when most needed.

Exclusive feeding on algaroba beans is not dangerous, but because of the richness of the feed it is better to feed some roughage with the beans. After being in the algaroba belt for some time, the cattle become ravenous for other feed and will eat leaves, twigs, and bark of shrubs and trees which are not touched at other times. Even the marsh plant (akulikuli) is eaten. On some of the ranches the watering troughs are placed so as to compel the animals to come out of the algaroba for water. In so doing they feed more or less on other plants. Ranch managers think that they are benefited by so doing. When milk cows are fed on algaroba, milk consumers complain of a bad flavor in the milk. In some cases, bowel troubles in children have been attributed to the feeding of the algaroba by dairymen.

One of the great problems of the ranches is to provide other forage to supplement the algaroba. Corn stover when shredded and baled partly solves the problem, but the quantity of such feed is too meager. Dry-land grasses and plants of the poorer kinds, grown just above the algaroba belt, must be relied upon to help in the solution of the problem, while saltbushes may aid upon salty lands near the coast. Sand

bur, yard grass, rat-tail grass, pili, Rhodes grass, and various annual weeds all help to supply the varied ration needed at this time.

MISCELLANEOUS FORAGE PLANTS.

Many other plants are fully as important for forage as some of the grasses and legumes. A number of our annual weeds are as nutritious and palatable as the grasses, and are, immediately following rainy seasons, the most important fattening feeds upon certain areas. A list of some of the more common species is given below:

Miscellaneous forage plants.

Botanical name.	Common name.	Hawaiian name.	Remarks on elevation and forage value.
Amaranthus palmeri [1]	Careless weed		
Atriplex leptocarpa [1]	Slender-fruited saltbush		Saltbushes are adapted to dry and alkaline soils.
Atriplex nummularia [1]	Round-leaved saltbush		
Atriplex holocarpa [1]	All-fruited saltbush		
Atriplex semibaccata	Half-berried saltbush		*A. semibaccata* is well established at Mokuleia on Oahu.
Atriplex nuttallii [1]	Arizona saltbush		
Batis maritima		Akulikuli	Eaten by cattle when in kiawe.
Bidens pilosa	Spanish needles	Ki, puaki, lauki	At all elevations, eaten by all kinds of stock.
Bœhmeria stipularis		Akolea	Shrub, leaves eaten by cattle.
Bœrhaavia diffusa		Alena	Leaves eaten by cattle and sheep, and roots by hogs.
Campylotheca spp		Kookolau	
Commelina nudiflora	Wandering jew	Honohono	In wet places, relished by cattle.
Cordyline terminalis		Ki or ti	Leaves eaten by cattle.
Eleocharis obtusa	Sedge	Kohekohe, pipiwai	Of little value, grazed by horses.
Erigeron canadensis	Fleabane	Ilioha, uwiuwi	Eaten by horses.
Erodium cicutarium	Alfilaria, "filaree"		Dry places; high elevations; well liked by sheep.
Erodium moschatum	do		Do.
Euphorbia lorifolia		Koko or akoko	Leaves eaten.
Eurotia lanata [1]	Winter fat, sweet sage		Dry places.
Freycinetia arnotti		Ieie	In forests, leaves eaten by cattle.
Gahnia beecheyi	Sedge	Uki	At elevations of 1,000 to 3,500 feet; eaten by horses and cattle.
Gossypium tomentosum	Wild cotton	Mao or huluhulu	Leaves eaten by cattle and sheep.
Haplostachys spp			Do.
Hypochæris radicata	"Dandelion"		Valuable annual on Haleakala.
Ipomœa sp	Wild morning-glory	Koali	
Jussiæa villosa		Pukamole	
Kyllingia monocephala	Sedge	Kaluha, pipiwai	Eaten but little.
Lampsana communis			Valuable annual on Haleakala.
Malvastrum tricuspidatum			Valuable on dry ranches.
Opuntia spp	Prickly pear, cactus	Papipi or panini	Valuable feed in time of drought, occurs from sea level to 2,800 feet.
Osteomales anthyllidifolia		Ulei	Berries and leaves eaten.
Phegopteris spp	Tangle ferns	"Akole"	
Plantago lanceolata	Rib grass, black plantain		Occurs from sea level to 4,000 feet; eaten by sheep.
Portulaca oleracea	Purslane	Ihi, akulikuli laulii	Widely distributed, liked by hogs.

[1] Introduced but not naturalized, rare.

Miscellaneous forage plants—Continued.

Botanical name.	Common name.	Hawaiian name.	Remarks on elevation and forage value.
Portulaca sclerocarpa		Ihimakole	At elevations of 2,000 to 5,000 feet less valuable than the preceding.
Prunella vulgaris	Self-heal		
Richardsonia scabra [1]	Mexican clover		Quite rare.
Ricinus communis	Castor bean	Koli	Leaves eaten by horses and cattle.
Salvia coccinea	Red sage	Lililehua	Very fattening for steers but causes abortion in cows.
Sanguisorba minor [1]	Field or sheep burnet		Similar to alfilaria, in dry regions, eaten by sheep.
Scirpus maritimus	Sedge		Of slight forage value.
Sesuvium portulacastrum		Akulikuli	In marshy places, eaten by cattle when in kiawe.
Sida spp		Ilima	Leaves eaten by sheep.
Sida sp		Kukailio	Leaves eaten by cattle and sheep, and oily seeds eaten by cattle.
Silene struthioloides			Fleshy root eaten by hogs.
Sonchus oleraceus	Sow thistle	Pualele	Very valuable annual at all elevations.
Taraxacum officinale	Dandelion		Valuable in higher lands.
Vaccinium reticulatum		Ohela	At elevations of 4,000 to 8,000 feet, leaves and berries eaten.
Xanthium strumarium	Cocklebur	Kikania	Leaves eaten by sheep and also by cattle when in cactus.

[1] Introduced but not naturalized, rare.

The sow thistle or pualele is found in every region and at all elevations; it is nutritious and palatable and well liked by all kinds of stock, including poultry, rabbits, and water buffalo. It is therefore one of the most important plants in this list.

Next to the sow thistle come common purslane and Spanish needles. These likewise are widely distributed, nutritious, and fairly well liked by stock.

At elevations above 3,000 feet the common dandelion and the two related composites, *Hypochæris radicata* and *Lampsana communis*, are valuable as fattening feeds.

Alfilaria at all elevations above 4,000 feet becomes valuable, especially for sheep. *Erodium cicutarium* is the true alfilaria. *E. moschatum*, however, is the more common species and is of greater value.[1] It is widely distributed on the Pacific coast and occurs from sea level to the snow line. *E. cygnorum* is native to Australia and very valuable in the drier portions of that country. Alfilaria is found in Hawaii at its best only at the higher elevations of the Parker ranch, the Humula sheep station, and Puuwaawaa, but it is found on Molokai, Haleakala, and other ranches in less abundance.

[1] U. S. Dept. Agr., Div. Agrostol. Bul. 2 (rev. ed.).

The species found on Haleakala is said to be different and less valuable than the one on Parker ranch and is probably *E. cicutarium.*

Alfilaria is an annual weed that comes up on unsodded areas, making a good growth of leaves during or following the rains and furnishing feed for cattle, and especially for sheep, for some time after the dry season opens.

Alfilaria grows and seeds at a lower level but does not seem to spread.

Field burnet is similar in habit to the alfilaria but, at lower levels, makes a greater growth of leaves and should be more valuable. In two trials at the experiment station it has produced no seed. It should be tried out at higher elevations.

The malvaceous plants, *Malvastrum tricuspidatum, Sida* spp., and *Gossypium tomentosum,* are excellent drought-resisting plants and furnish considerable forage. The ilima is very common upon Lanai and Molokai and is closely grazed by sheep. Another species of Sida, known as kukailio, is valued also for its oily seeds, which are well liked by cattle.

In wet regions one of the most valuable feeds is honohono. Among the dairymen at Glenwood, Hawaii, honohono is considered their most valuable "grass." They rely chiefly on this and Para grass for roughage.

Black or narrow-leaved plantain was introduced as "rib grass" from Australia. It has some forage value for sheep. It is considered undesirable in most places, and even Australia has now put it in the list of obnoxious weeds.

The saltbushes. There are many species of saltbushes, nearly all of which furnish forage. They are tolerant of alkali and resistant to drought, and are held in high favor by ranchmen in California, Arizona, and in Australia. Several species have been tried out in Hawaii. The half-berried saltbush fully covers a small field near Mokuleia, Oahu. This field, however, has not been grazed for several years. In adjoining paddocks only occasional plants are found, but these were closely grazed by the cattle. On Molokai the same species and also some of the Arizona species were tried. When protected from stock the plants did well, but the cattle when in the kiawe became so ravenous for other feed that they eradicated the saltbushes.

It may prove feasible in attempting to establish saltbushes to obtain seed enough for a larger area and then protect it until the plants are well rooted. A few isolated plants in early stages of growth stand little chance against the grazing of a large herd.

Batis maritima and *Sesuvium portulacastrum,* both known as akulikuli and both grown in salt marshes, are not ordinarily eaten by stock, but during kiawe season they are readily consumed.

The members of the sedge family furnish but little grazing. Usually they are coarse, fibrous, innutritious, and rather unpalatable to stock. The few that are named furnish some feed.

The list includes besides the above mentioned a number of native trees, shrubs, vines, ferns, herbs, and roots, all of which furnish some feed for stock; also a few introduced species, not yet established.

The prickly pear (*Opuntia* sp.). The cactus known as prickly pear, or panini, is one of the important forage crops of Hawaii. On some ranches there are large areas fairly well covered with this plant. On Ulupalakua, for example, there are 2,000 acres, on the Haleakala ranch 1,500 acres, on leeward Hawaii 10,000 acres.

Stock eat cactus chiefly during the dry season when other feed is wanting. In Texas it is said that cattle on cactus range drink about once weekly in winter months and in summer months two or three times. In Hawaii there are cattle 3 and 4 years old that do not know the taste of water or how to drink it. The cactus is both feed and drink for them. Besides being used as a pasture for certain cattle at all times, the cactus fields serve as insurance against loss of cattle during extreme drought. At such times the cattle are brought from other pastures. They soon learn to feed on the cactus, and when all the fresh lower joints are consumed the upper portion is cut for them from day to day. In the Southwestern States the spines are burned off or softened by steaming before feeding. In Hawaii the spines are not removed.

Cactus is an emergency feed for the beef producer, but is of value at all times to a dairyman, since it can largely replace silage as a succulent feed in a ration for the dairy cows. This feed may cause an odor or bitter flavor in the milk and may produce blue milk and pale butter. One dairyman fed 100 pounds of cactus, 9 of brewers' grains, and 3 of cottonseed meal with good results. Another recommends 35 pounds chopped cactus, 3 quarts bran, and 1 quart cottonseed meal twice daily when the cattle have a little outside pasture. For fattening mature steers from 100 to 200 pounds of cactus daily is recommended along with from 1 to 6 pounds of grain feed.

The following table gives the composition of cactus in Hawaii:[1]

Composition of Hawaiian prickly pears.

	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Young fronds	94.63	0.44	0.07	3.22	0.52	1.12
Old fronds	94.62	.39	.09	3.16	.61	1.13

[1] Hawaii Sta. Bul. 13.

The younger fronds are slightly superior to the old ones. It must also be remembered that the plant requires a longer time to recover when the older parts of the plant have been severed. It requires from two to seven years for the plant to replace itself, depending upon the amount which is cut down, the age of the plant, the season, and whether or not the older trunks are cut.

A yield of 68⅔ tons was obtained from a growth of 31 months, equal to 22 tons per acre annually from a cultivated crop. When no cultivation was given and grass allowed to grow, the yield was only one-eighth of this amount. In the above tests the plants were planted 2 by 6 feet apart.

At Haleakala ranch on Maui the manager informs the writer that in a field of 1,500 acres of cactus (Pl. IX, fig. 1) he keeps a total of 700 head of different ages throughout the entire year.

Dr. Griffiths is of the opinion that the spineless cactus can not replace the spined forms on ranches. It is less hardy, grows more slowly, must be cultivated in order to furnish any considerable amount of feed, must be fenced to protect it from the cattle, and finally must be cut and hauled out to the cattle, since, if allowed access to it, the cattle will surely kill it.[1]

In Hawaii there are several different forms of cactus, some of which are nearly spineless, but the larger areas are covered with the spiny forms having purple or whitish fruits.

Aside from its use as forage, the prickly pear is used in some regions as food for man, either raw or in jellies. The young joints are often pickled or cut and dried. The expressed juice is used in whitewash for exterior work. The pulp is used for poultices and for making cactus candy. The ripe fruit in some parts of Hawaii is considered especially valuable as food for swine, and the latter animals also to some extent make use of the fronds if the spines have been well burned or cut.

Cacti require a warm climate with an intermittent rainfall. In Hawaii they thrive on the leeward sides of the islands at elevations between 300 and 2,500 feet. They may be propagated by seeds, but are very easily propagated by cuttings. Any portion of the plant placed in the soil will take root and grow.

LESS IMPORTANT GRASSES.

The following table gives a list of the less important grasses which have been introduced into Hawaii:

[1] U. S. Dept. Agr., Bur. Plant Indus. Buls. 74, 124.

FIG. 1.—A PRICKLY PEAR PASTURE, HALEAKALA RANCH.

FIG. 2.—A ROCKY PASTURE WHERE ONLY ANNUAL WEEDS AND GRASSES ARE FOUND.

Grasses introduced for range improvement but not yet established.

Botanical name.	Common name.	Adapted to region.
Agropyron smithii	Blue joint	
Agropyron spicatum (2)	Blue joint or gumbo grass, wire bunch.	Dry.
Agropyron tenerum (2)	Slender wheat grass	Do.
Agrostis alba	Fiorin	
Agrostis alba var. *stolonifera*	Creeping bent	Moist.
Agrostis scabra	Tickle grass	
Agrostis vulgaris	Herd's grass, redtop, or Rhode Island bent.	High, wet.
Alopecurus pratensis	Meadow foxtail	High.
Andropogon saccharoides (1)	Feather sedge or fuzzy top	Dry.
Andropogon sericeus (1)	Australian blue grass	Do.
Andropogon sorghum (var.) (1)	Sudan and Tunis grass	Moist to dry.
Arrhenatherum elatius	Tall meadow oat grass	Moist.
Astrebla pectinata (3)	Mitchell grass	Dry.
Astrebla triticoides (3)	....do	Do.
Avena fatua	Wild oat	
Bouteloua curtipendula (2)	Tall grama or side oats	Do.
Bouteloua hirsuta (2)	Hairy grama or black grama	Do.
Bouteloua oligostachya (2)	Blue or white grama	Do.
Bromus inermis (2)	Smooth brome grass	Dry, high.
Bulbilis dactyloides (2)	American buffalo grass	Dry.
Calamagrostis langsdorfii		
Cenchrus montanus		
Chloris ciliata	Finger grass	
Chrysopogon montanus		Do.
Cynosurus cristatus	Crested dogstail	
Danthonia pilosa (3)	Wallaby grass	Do.
Danthonia semiannularis (3)	....do	Do.
Eleusine ægyptiaca (1)	Crowfoot grass	Dry, low.
Elymus condensatus (2)	Western or giant rye grass	Dry.
Eragrostis abyssinica	Teff	Dry, low, or medium.
Eragrostis brownii (3)		Dry.
Eragrostis leptostachya		
Festuca duriuscula	Hard fescue	
Festuca elatior	Tall fescue	Moist, high.
Festuca ovina	Sheep fescue	High.
Festuca ovina var. *tenuifolia*	Fine-leaved fescue	Moist, high.
Festuca pratensis	Meadow fescue	High, moist.
Festuca rubra	Red fescue	Do.
Festuca rubra (var.)	Chewing's fescue	Dry.
Festuca viridula	Oregon bunch grass	
Hilaria cenchroides (2)	Curly mesquite or southwestern buffalo grass.	Do.
Hilaria mutica (2)	Black grama, galleta or cracker grass	Do.
Leptochloa virgata (1)	Judd grass	Moist.
Lolium italicum	Italian rye grass	Moist, high.
Lolium italicum var. *westerwoldicum*		
Lolium sp	North of Ireland rye	Do.
Lolium sp	Poverty Bay rye grass	
Melinis minutiflora (1)	Molasses grass, or Brazilian grass	
Muhlenbergia porteri (2)	Black grama	
Panicum bulbosum (2)	Bulbous panic grass or alkali saccaton.	
Panicum lachnanthum		
Panicum lanatum		
Panicum spectabile		
Panicum texanum	Colorado grass or Texas millet	Low, wet.
Paspalum elegans		
Paspalum floridum		
Paspalum nodosum		
Paspalum stoloniferum		Low, moist.
Paspalum virgatum (1)		Moist.
Phalaris commutata	Canary grass	Medium, moist.
Phleum pratense	Timothy	
Poa annua (1)	Annual meadow grass	High, moist.
Poa aquatica	Water meadow grass	Wet.
Poa arachnifera	Texas blue grass	Moist.
Poa compressa	Canadian blue grass	
Poa nemoralis	Wood meadow grass	
Poa senegalensis		
Polypogon sp		
Sporobolus cryptandrus (2)	Dropseed	
Sporobolus indicus (3)	Smut grass	Dry.
Sporobolus wrightii (2)	Saccaton	Do.

The list of grasses introduced for improvement of Hawaiian pastures is a good index of the desire and efforts of stockmen to improve their conditions. The grasses in the above list are not yet naturalized. The grasses marked with (1) were mentioned with the more important grasses because of relationship or similar habits of growth. In Australia *Eleusine ægyptiaca* is spoken of as being a better grass than *E. indica*, but the latter is much more common in Hawaii. The grasses marked with (2) are some of the better grasses found upon the dry plains of the western United States, and those marked (3) are mentioned in Australian publications as being very valuable upon their dry lands.

None of the American grasses has succeeded, although the tall grama or side oats grama has been quite favorably mentioned, and fuzzy top has succeeded to a small degree upon Niihau and Kauai. Several of these, including the grama grasses, the buffalo grasses, the saccatons, the agropyrons, and smooth brome grass are so valuable under the dry conditions of the West that it seems as if more determined efforts should be made to establish these on the dry lands of Hawaii. One thing must be kept in mind in regard to new grasses, the finer the grass or the more palatable, the closer will the stock keep it grazed and the less chance will it have to reseed itself, to spread, or to survive the dry season. Secondly, the smaller the areas seeded to a new grass, the less chance does it have to succeed under range conditions. The seeding of somewhat larger areas and protecting until better established might aid in overcoming the difficulties. The failure of many of these grasses may be attributed to poor seed or to bad weather conditions. In Hawaii grasses are somewhat hard to start; the seeds are small and if planted deeply the young plants never come through to the surface. If planted shallow, the seed sprout with good conditions of moisture but the surface layer of soil dries rapidly on account of wind and sun, and the young plant dies before being able to root well and secure moisture from the damp soil beneath.

Of the Australian grasses mentioned in this list only the smut grass is spreading. This is found on all islands, and may be native. It is more common in Kula than elsewhere, according to the observation of the writer. It is very drought-resistant, but tough and wiry and better feed for horses than for cattle. It is so persistent, however, that it might be of value with other secondary grasses, like sand bur and yard grass, for planting adjacent to algaroba belts. The Mitchell and Wallaby grasses and *Eragrostis brownii* should be given further trial.

Of the other grasses, *Chrysopogon montanus* has shown up well in trials at the experiment station, teff grass is an important grass on the dry plains of Northern Africa, *Panicum bulbosum*, *P. spectabile*,

and *Cenchrus montanus* thrive on Haleakala at 2,000 feet or more. The species of Agrostis, Festuca, and Lolium prefer rather moist conditions at higher elevations. *Phalaris commutata* is said to be a poor variety of *Phalaris bulbosa* but has given some promise for medium elevations. Texas blue grass is an important winter grass of the extreme South and should thrive in Hawaii during the winter months. Neither Texas blue nor *Phalaris commutata* seeded in station trials but are easily propagated by division of the roots.

RECOMMENDATIONS FOR PLANTING.

For marshy places: Such grasses as Para grass, Colorado grass, or honohono are probably the best. If not too marshy *Paspalum dilatatum* might succeed. Guinea grass also requires plenty of moisture.

For high wet districts: *Paspalum dilatatum*, sweet vernal grass, Kentucky blue grass, orchard grass, perennial rye grass, white clover, hop clover, and possibly alsike clover.

For high dry regions: Kentucky blue grass, orchard grass, perennial rye grass, rescue grass, Yorkshire fog or velvet grass, *Paspalum dilatatum*, alfilaria, field burnet, Indian clover, and bur clover.

For medium elevations, moist: *Paspalum dilatatum*, Bermuda grass, buffalo grass, Texas blue grass, *Paspalum compressum*, *Paspalum virgatum*, crab grass, rescue grass, Spanish clover, and bur clover.

For medium elevations, dry: *Paspalum dilatatum*, Rhodes grass, Natal redtop, fuzzy top, Bermuda, side oats or tall grama, crab grass, Spanish clover, bur clover.

For lower elevations, moist: *Paspalum dilatatum*, Natal redtop, Rhodes grass, Bermuda, yard grass, *Desmodium triflorum*, Spanish clover, bur clover.

For lower elevations, dry: *Paspalum dilatatum*, Rhodes grass, Natal redtop, fuzzy top, yard grass, smut grass, buffalo grass, bur grass, crab grass, kakonakona, etc.; *Desmodium triflorum*, Spanish clover, bur clover; and salt bushes, ilima, pualele, prickly pear (also the spineless forms), and algaroba.

Upon the low dry lands the problem of forage crops is more difficult to solve. The annual grasses and weeds coming with the rains are soon devoured. The tenacious, drought-resisting grasses which survive long dry spells are unable to produce much feed during such times. The result is that feed soon becomes scarce, the annuals are so closely cropped that no seed is formed, and the pastures therefore deteriorate from year to year.

The most valuable grasses for low dry regions are those *which will withstand long drought and close cropping by live stock.* For these reasons buffalo grass, Bermuda grass, *Paspalum dilatatum*, sand bur or bur grass, yard grass, and possibly smut grass are especially

valuable. Where resting of paddocks is possible and overstocking never allowed, pili, fuzzy top, Natal redtop, Rhodes grass, and some of the newly introduced grasses, like Sudan grass and *Chrysopogon montanus*, are to be recommended.

PLANTING GRASSES.

The rocky steep slopes of the ranch lands of Hawaii can not be plowed and prepared for seeding as is done for cultivated crops. (Pl. IX, fig. 2.) Upon each ranch, however, there is some land which may be fitted in this manner for seeding. Whether or not it will pay to do so depends on local conditions. Klu, guava, pilipiliula, etc., can not furnish much feed. It would be unwise to destroy them, however, if the conditions are such that good grasses will not thrive. The cost of clearing, plowing, fitting, and seeding may vary from $30 to $50 per acre and would be justified only on windward sides of the islands, where a good rainfall insures feed at all seasons. In fields sodded with pilipiliula, but clear of guave, lantana, or klu, it will usually pay to plow whether or not other native grasses and weeds are needed. The pilipiliula is easily killed by plowing and the other native grasses and weeds which come up greatly exceed pilipiliula in feeding value.

A cheaper but less thorough method consists in preparing narrow strips of land in the upper pastures at right angles to the prevailing wind and seeding these strips to improved grasses. This allows the grasses to seed, and the wind carries the seed upon the areas between the strips. In practice, however, the stock can not be kept off long enough for the seeding, and they graze tame grasses so closely that no seed is formed. The smaller the percentage of the area thus planted the less likelihood there is of the formation of seed and the spread of the plants. One or more of these strips should be fenced to protect the grasses until seed is formed. One of these strips (or part of one strip if there is but one) should be left with protection as a place from which to obtain seed for further plantings upon the ranch.

Another method consists in running furrows at intervals across the fields and planting these to grass. Single furrows break up the old turf, pulverize a small portion of soil, and improve conditions enough to give other grasses a fighting chance. Unless one knows the comparative vigor of the old and the new species, such preparation may be wasted effort.

Another plan, and one used in experimental planting generally, involves fencing an acre or two, preparing the land thoroughly, dividing it into plats for various grasses, and, after seeding, leaving them under protection until all have seeded, when the fence may be removed and the struggle for existence under range conditions

observed. If only one grass or a mixture is used, no plat subdivisions are necessary.

The cheapest plan, but hardly the most economical, is to plant without any preparation. The seed may be scattered broadcast from the saddle, and in this way the most inaccessible parts of the paddocks will receive seed. For many range grasses this method is fairly efficient, but for others some preparation of soil is preferred. Some seeds are able to bury themselves, while others require shallow covering by hand or tool or by heavy downpours of rain. With expensive seed it is always better to prepare the soil and lightly cover the seed.

Extension of plantings of grasses may be accomplished by grazing the stock upon them when full of ripe seed and allowing the animals to roam over various paddocks. According to Munro [1] the seeds of some grasses, particularly those of *Paspalum dilatatum*, are improved in germinating quality by passing through animals.

Mixtures of grass seeds are desirable. Some root more deeply than others, and thus draw upon different portions of the soil. Some spring up more quickly after rains, or with less rain. Some endure under wet or dry conditions longer than others. Some are less palatable than others, and are eaten when the better ones are gone. Many annuals thrive with perennials, and many legumes with the grasses.

With such grasses as manienie, buffalo grass, or Para grass the only quick method of seeding is to use portions of the running stems. Many other grasses, such as Guinea grass, Rhodes grass, and *Paspalum dilatatum*, are more surely propagated by planting out divisions of the roots.

With seed that is scarce and high in price it will often prove more economical to plant the seed in beds, giving irrigation as needed, transplanting the seedlings to the large fields during a rainy period, keeping all stock fenced out until the plants are firmly rooted.

MANAGEMENT OF RANGE LANDS.

On this subject no formulas can be given which will apply to all the ranch land in Hawaii, because of variations in conditions and the nature of the forage plants. Most paddocks are benefited by resting for a given period annually. Kentucky blue grass pastures fail in dry weather and have to be rested. Annual grasses and weeds grow for a comparatively short season.[2] It is important to remember that unless new seeds are formed such pastures may be ruined. Overstocking results in the disappearance of valuable grasses and

[1] Hawaii. Forester and Agr., 4 (1907), p. 247.

[2] Plate IX, figure 2, shows a rocky pasture in which annual weeds and grasses only are found. There are large areas of such lands in Hawaii.

weeds, because no seeds can form to continue the species. With such grasses as manienie, Hilo grass, and maulaiki, which are most palatable when young and tender, and which are not destroyed by overstocking, continual grazing may be practiced with benefit to the pastures. Such pastures are also benefited by occasional burning to destroy the old, dried growth, insect larvæ, and vermin. During dry seasons care is necessary to avoid fires.

UNDESIRABLE AND POISONOUS PLANTS.

The following table gives a list of the undesirable and poisonous plants that are met with upon some of the Hawaiian ranches:

Undesirable and poisonous plants.

Botanical name.	Common name.	Hawaiian name.	Remarks.
Acacia farnesiana [1]		Klu	
Andropogon halepensis (var.) [1]	Johnson grass		Difficult to eradicate.
Asclepias curassavica [2]	Milkweed	Nuumela, kilika	Cases of poisoning reported from Oahu.
Chætochloa glauca [1]	Yellow foxtail		Widely distributed on Kauai.
Chrysopogon aciculatus [1]		Pilipiliula	
Cnicus (?) sp.[1]	Common thistle		
Eupatorium sp.[1]		Pamakani	Occupies large areas on Maui.
Euphorbia lorifolia [2]		Koko, akoko	Contains poisonous ingredients.
Lantana camara [1]	Lantana		
Leucæna glauca [2]	Koa bush	Koahaole	Said to cause falling of hair from horses' tails.
Momordica charantia [1]	Chinese cucumber		
Paspalum orbiculare [1]	Rice grass	Mau-laiki	
Passiflora fœtida [2]			Contains poisonous ingredients.
Psidium guayava [1]	Guava		
Ricinus communis [2]	Castor bean	Koli	Causes abortion.
Rubus jamaicensis [1]	Thimble or Hitchcock berry.		
Salvia coccinea [2]	Red sage	Lililehua	Do.
Tephrosia purpurea [2]		Auhola	Contains poisonous ingredients.

[1] These plants crowd out and replace the plants which have forage value.
[2] Poisonous.

CULTIVATED FORAGE CROPS.

Cultivated forage crops include sugar cane, corn, sweet and non-saccharin sorghums, Para grass, Guinea grass, Rhodes grass, oats, wheat, barley, millet, teosinte, alfalfa, cowpeas, soy beans, velvet beans, jack beans, peanuts, pigeon peas, horse beans, Canada peas, hairy vetch, winter vetch, cassava, sweet potatoes, sugar beets, mangel-wurzels, turnips, rape, carrots, honohono, spineless cactus, kale, cow pumpkins, etc.

Sugar cane furnishes a large amount of excellent feed in the form of cane tops and molasses. Sorghum is fed green also, as is sometimes corn. In the corn belts proper only little of the stover is saved, the grain being the principal thing desired. Corn as green feed, as stover, or as silage could be more generally used as a source of feed.

Para grass, Guinea grass, honohono, and alfalfa are fed principally in the green state. The only cured feed put up in the islands is that made from corn, alfalfa, and Rhodes grass. Cured hay is thought to be unnecessary, but more should be stored for reserve feed in times of shortage. Curing, especially of alfalfa, is impossible in some places because of the moist air. In other places it is difficult, and it is only at intervals or at certain seasons when it is possible at all. More alfalfa hay would be put up were it not for this fact.

These are the principal cultivated forage crops, the others being comparatively rare. It is hoped to emphasize cultivated forage crops more in a later report.

CONCLUSION.

This publication includes the reports of several of the ranch managers and the observations of the writer made upon a few of the ranches and is not considered exhaustive. Several of the ranchmen did not report when requested. Otherwise the published report might be more complete.

The only available printed matter upon the subject of grasses were the articles in the Hawaiian Forester and Agriculturist, by C. C. Munro, and those in the annual report of the Livestock Association; also Hillebrand's Flora of the Hawaiian Islands. Copies of the report on grasses by G. C. Munro to the American Sugar Co., in 1903, 1904, and 1905 were available, and these reports are very complete. The report of W. F. Sanborn, of Hanalei, deserves special mention also for its completeness. The writer wishes to acknowledge the receipt of reports (verbal or written) and of courtesies extended by L. von Tempsky, G. P. Cooke, W. F. Sanborn, A. W. Carter, G. C. Munro, Eben Low, O. Ludloff, F. A. Clowes, A. McPhee, D. T. Fleming, A. F. Judd, Francis Gay, and H. J. Lyman. Thanks are also extended for botanical identification of plants to Prof. J. F. Rock, of the College of Hawaii, and especially to C. N. Forbes, of the Bishop Museum; and for a review of the manuscript and suggestions given by Jared G. Smith, who was formerly in charge of this station and instrumental in introducing many of the grasses reported upon herein.

It is to be hoped that the live stock men will be helped in their efforts at range improvement by this report; that they will become more interested in noting the forage value of different plants; that they will continue to experiment with various grasses and other plants; and that they will report any mistakes herein committed as well as any additional information worth while to the experiment station in order that any later report may be made more valuable.

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